ON THE PREDICTION OF FRONTAL POSITIONS

by

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The placing of fronts on a prognostic chart is a difficult problem and has never been thoroughly investigated. In the construction of such charts, models and experience generally must be used to place the frontal systems.

As noted in Riehl et al., Forecasting in Middle Latitudes,[1] we have no method to predict first the frontal positions and from these deduce the position and intensity of the low pressure centers to be expected. On the contrary, we must at first predict the cyclones from other considerations and then enter the fronts with the aid of models. It is the objective of this study to place these models on a more quantitative footing and to find the most probable frontal position to be entered on prognostic charts, given a 500-mb forecast and a prediction where the surface lows will be situated and what their relative intensity will be.

Experience has shown that the frontal penetration between successive low centers is limited to some fraction of the distance between these lows. A rule of thumb has been to use a value one-fourth to one-half of this distance, when measured normal to a line connecting the two centers. Here we shall try to determine the value of this rule and also to see if additional parameters can be introduced. Only North America and the western Atlantic are considered.

Surface and 500-mb charts were examined for October through March, 1946, 1949 and parts of 1945, 1947, and 1950. Surface charts for December 1903-06 and 1924-26 also were included in the study in order to deal with a sample from a wide spread of years.

Table 1 gives the percent frequency of the amount of cold front penetration as a percentage of the straight-line distance between successive lows. The average penetration is 51% and the distribution about the mean is approximately normal. The sample includes 126 cases.

Since this table shows such a marked peak near 50%, this value is certainly the best first approximation. What is now needed is to be able to tell when the penetration will be near this value and when large departures from this average will occur.

To accomplish this, the data were retabulated with respect to three parameters, 1) longitude of the leading low, 2) relative intensity of the lows involved, 3) position of the 500-mb trough.

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[1]AMS Monograph #5, 1952.

1) For this breakdown, the data were divided into four groups as follows:

a) east of 80°W,
b) between 80° and 90°W,
c) between 90° and 100°W,
d) west of 100°W.

The results were such as to permit a simplified grouping: Leading low

a) east of 90°W,
b) west of 90°W.

Table 2 shows that there is a tendency for the penetration to exceed 50% when the low is west of 90°W and to be less than 50% when the low is east of 90°W. This result was anticipated and may be related to topographic features of the United States. Over the western plains, cold air masses are accelerated southward because of the banking effect of the Rocky Mountains.

2) For the computation of the relative strength of the lows, the pressure difference between the central isobars was used. As the historical map series contains 5-mb isobars, the limits chosen were

a) pressure of leading low 10 mb or more lower;
b) pressure difference ± 5 mb;
c) pressure of leading low 10 mb or more higher.

As the last group contained very few cases, Table 3 only considers the first two class intervals, each of which contains over 40% of the cases. We see -- perhaps surprisingly -- that the frequency distribution of the upper row of Table 3 is quite similar to Table 1. It provides no additional information except to point out that cold fronts may be stalled readily even when the leading low is much more intense than its successor. When the intensity of the lows was nearly equal, however, the penetration was distinctly sub-average.

3) In considering the position of the 500-mb trough, the question asked was as follows: Is a 500-mb trough associated with the leading low, or is the trough to the rear of both lows, so that the flow is relatively straight between them? In answering this question, it should be kept in mind that the Historical Map Series is printed on very small scale maps. Although the flow may be pictured as roughly straight on these charts, larger-scale base maps are likely to reveal a weak short wave trough connected with the leading low. Thus the classification discussed here is rather qualitative. According to Table 4, little help is obtained for the forecast when a marked trough is associated with the leading low. This is in accord with the upper row of Table 3. The parameters used for the preparation of Tables 3 and 4 probably are partially correlated and the similar result therefore is as should be expected. Correspondingly, cold front penetrations average below the mean when the flow between the lows is relatively straight and when only a weak upper trough is present between them.

Conclusion: This study has shown that in the absence of other information, a cold front should be entered on prognostic charts for North America and the western Atlantic so that its farthest penetration on that particular map, when measured normal to the line connecting two successive lows, is 50% of the length of the line. The following modifications also have been suggested:

1) If the front lies east of 90°W, the penetration is apt to be sub-average; if it lies west of 90°W, above average.

2) If succeeding lows have about equal strength the penetration will tend to be sub-average.

3) If the 500-mb flow between these lows is without marked trough, the penetration again is likely to be sub-average.

In future work the following steps may be taken:

1) Extension to a larger sample.

2) Inclusion of other parameters, especially direction of motion and speed of the lows. Qualitatively, we have the rule that penetration is proportional to the meridional component of motion of lows and inversely proportional to their speed. Evidently, these rules will only verify within certain broadscale settings. They are also correlated in part with the parameters here considered.

3) Eventual combination of all parameters located into a single forecast graph.

Per Cent Penetration	0-19	20-39	40-59	60-79	80-99	100-119
Per Cent Frequency	0	26	49	20	3	2

Table 1--Frequency distribution in per cent of the amount of cold front penetration. Displacement given as per cent of distance between lows. (125 cases)

Long. \ Displacement in per cent	< 30	30-49	50-69	≥ 70
W of 90°	14	28	47	11
E of 90°	9	60	20	11

Table 2--Per cent frequency of amount of cold front displacement vs. longitude of primary low. Displacement given as per cent of distance between lows. (98 cases)

Press. Difference \ Displacement in per cent	< 30	30-49	50-69	≥ 70
≥ 10 mbs	16	32	40	12
< 10 mbs	18	41	32	9

Table 3--Per cent frequency of amount of cold front penetration vs. pressure difference between lows (positive value indicates leading low more intense). Displacement given as per cent of distance between lows. (63 cases)

Displacement in per cent	20-39	40-59	60-79	≥ 80
Trough	21	48	26	5
No trough	57	33	11	0

Table 4--Per cent frequency of amount of cold front penetration vs. 500 mb trough condition. Displacement given as per cent of distance between lows. (65 cases)